The movement observed was in disaccord with the prediction of theory. In fact the major axis of Hyperion's orbit, instead of moving, directly, round Saturn in a century, accomplished a revolution in the opposite direction in the short period of eighteen years.

Newcomb has proved that this rapid retrograde revoution is caused by the perturbing action of the next satellite Titan.

In the various volumes of "The Astronomical Papers for the use of the American Nautical Almanac," Newcomb has published a great number of memoirs. One can follow step by step the immense progress achieved in the execution of the vast project which he had taken upon himself to accomplish.

It is difficult to convey an idea of the considerable efforts, the sagacity which must be displayed, the numerous investigations which must be accomplished, in order to make known to a sufficient degree of approximation the motion during a century of a body of our planetary system. Only those scientific men who have given themselves up to analogous studies can appreciate the enormous expenditure of physical and intellectual energy which must have been necessary to Newcomb in order to bring to a happy end the researches on the four planets nearest the sun. Newcomb has based his work on more than 60,000 observations, which he has compared with Le Verrier's tables; the perturbations have been calculated with great precision. While Newcomb has thus founded theories of these planets on a more precise basis, his celebrated collaborator, Mr. Hill, has obtained the same results for the two planets Jupiter and Saturn.

Henceforth, science will profit by the fruits of this immense labour, consisting of the tables of the planets Mercury, Venus, Mars and the Earth. In a special volume there are to be found various researches on the fundamental constants of astronomy.

We have only been able to give a short sketch of Newcomb's achievements; he is gifted with a prodigious power of work, which is testified by the extraordinarily long list of his researches.

The reception which has been accorded to them by all competent men points to their author as one of the most illustrious representatives of celestial mechanics.

This activity has embraced the most diverse branches of astronomy. Not only has he given a great scope to the intellectual movement of his country, but he has also contributed in a very successful manner to elevate the level of the civilisation of our age, enriching the domain of science with beautiful and durable conquests.

LOEWY.

THE TEMPERATURE-ENTROPY DIAGRAM.

The Entropy Diagram and its Applications. By J. Boulvin, Professor at the University of Gand, Belgium. Translated by Bryan Donkin. Pp. xii + 70. (London: E. and F. N. Spon, Ltd., 1898.)

RANKINE'S "Thermodynamic Function ϕ" (defined by $t.d\phi = dH$) is now called "Entropy ϕ." The state of a pound of stuff which has only fluid stress and strain is completely defined when we know the values of any two of p, v, t, E or ϕ [during change of state the two must not be merely p and t] where E is the intrinsic energy and ϕ is the entropy. When we say that E returns to its old value if we bring the stuff to the same state again, we state the first law of thermodynamics in its most general form. When we say that ϕ returns to its old value, we state the second law of thermodynamics in its most general form.

A curve connecting the values of any two of the above coordinates will, therefore, completely define the changing state of a pound of stuff. Rankine does not seem to have used the t,ϕ coordinates graphically, but he used them very much indeed in the algebraic form; and the idea that a t,ϕ diagram might be constructed was published by several mathematicians more than a quarter of a century ago. In truth, the idea was familiar to all students of Rankine, but until Mr. Macfarlane Gray began his crusade in favour of the use of the t,ϕ diagram in practical steam engine calculation, no other person had any idea of the changes that its use would effect.

When a pound of water-stuff alters in pressure and volume in any assigned way, at what rate does it receive or give out heat? This is the problem that we used to solve in the most laborious way; and so troublesome was it that I question if anybody, not a lecturer, ever worked out more than one example completely. The problem was never put before any but the most advanced students.

Now, thanks to Macfarlane Gray, this sort of problem is not only taken up and solved by the average student in the most elementary classes, but it is of all problems the one whose solution is most easily understood; and it is through such work that we now most easily introduce the average student to the laws of thermodynamics and the properties of steam and water. For twelve years it has been one of the commonest of class problems to take an indicator (or p,v) diagram, and assuming a certain wetness of the steam at the beginning of the expansion, to convert it into a $t\phi$ diagram.

Prof. Boulvin has not added to our knowledge of theory or the practical application of the $t\phi$ diagram, but in his well-known "Cours de Mécanique appliquée aux Machines," in 1893, he made the method known to continental students, and exhibited the conversion of pv to $t\phi$ coordinates in a fourfold diagram; whereas in England such a conversion has always been on one diagram. Our method has possibly been such that the result is confusing to all but the man who carries it out; but this is the fault of all graphical methods of working problems. It has the merit of utilising the whole of a sheet of paper instead of one quarter of a sheet. The English method may be recommended to a student who wants an accurate answer. Prof. Boulvin's method may be recommended to a lecturer who wishes merely to *illustrate* the connection between the p,v and the $t\phi$ diagrams.

The solution of the problem is really very misleading, for, invariably, the assumption is made that there is no moisture in the cylinder at the end of the exhaust. This assumption is the basis of the method used by Hirn and his numerous followers in that kind of study of the steam engine which is usually supposed to be complete. It does not seem to be understood that if there is any moisture in the cylinder at the end of the exhaust, Hirn's elaborate analysis is utterly wrong; and yet there is every ground for believing that even when steam is somewhat superheated when leaving the boiler, even well-jacketed cylinders are never free from moisture. I am sorry to say that the Hirn analysis is often employed for cylinders with no jackets when the steam supplied is known to be quite moist. As an academic exercise, no one would object to the method of study if students were informed of its uselessness in most practical cases, but, unfortunately, this information is never given in treatises which advocate the method.

If there is no leakage past the piston, we are sure that, from the beginning of the expansion to the release, we are dealing with the volume and pressure of a quantity of stuff which does not alter in amount. This is only a portion of an indicator diagram; and, as I have already pointed out, our usual study of it is based upon an unwarrantable assumption. But what are we to say of men like Prof. Boulvin, who pile upon this Pelion, Ossas of further assumption for the sake of making pretty academic problems, and then publish the solutions of these problems as if they were of practical importance?

Of course we may, if we please, say that when steam is released to the condenser, we can imagine the whole change as occurring in the cylinder itself; only we ought to remember that we are substituting a very simple hypothetical process for a very complicated reality, which has almost nothing in common with it. We ought to remember that the very pretty, beautifully complete, cyclic $t\phi$ diagrams, which we obtain from childish assumptions, may get to be looked upon by students, and even by ourselves, as having a real meaning.

The engineering teacher is much too apt to fill up the time of students with an elaborate and systematic course of instruction on a subject in which only a few lessons are essential, and, indeed, in which only a few lessons ought to be admissible. In some German schools we have systematic courses on graphical statics lasting whole terms or years. Courses on practical geometry are never supposed to be of use unless the student draws every imaginable kind of curve, draws every imaginable kind of intersection of surfaces. When some man who really thinks for himself has, after endless opposition and worry, convinced teachers that a certain kind of exercise is of value, his converts make his modest proposals into an elaborate academic system. There is no imaginable problem which does not become part of an elaborate course of exercise work. A student becomes wonderfully learned, but he loses the power to think things out for himself. Macfarlane Gray's method of study may be made part of a student's mental machinery in a few lessons, and in these few lessons it enables an elementary student to do easily what Hirn did with so much trouble; but, in truth, its great value lies rather in its enabling students to work out for themselves the well-known results of Rankine and Clausius. They see at a glance that liquefaction accompanies adiabatic expansion. They very quickly find the p,v law of adiabatic expansion of steam of any wetness. They can calculate easily the work that would be done by a perfect steam engine using the Rankine cycle, and many other important things which the average student used to take on trust. Not only does the $t\phi$ diagram enable one to see at a glance the reasonableness of much that used to be very obscure, but it clears the ideas of men who still prefer to work algebraically.

It is quite usual now in classes for students to prepare for themselves $t\phi$ sheets on which not only are the $t\phi$ lines for a pound of water and a pound of steam laid down, but also lines of constant p and constant v and constant E for wet, and also for superheated steam; and with these sheets many interesting problems may be worked.

The $t\phi$ sheets for a perfect gas, with lines of constant p, v and E, are even more valuable than such sheets for steam when one desires to convert an indicator diagram of a gas or oil engine into a $t\phi$ diagram. But, indeed, the $t\phi$ diagram is nothing like so valuable in gas engine work as in steam engine work, for rate of heat reception is quite easily obtainable from the p,v curve of a perfect gas. When we also remember that all idea of time is absent from a $t\phi$ curve, it will be seen that practical gas-engine people are not likely to make much use of it.

Prof. Boulvin introduces his subject by a chapter on the laws of thermodynamics. He begins with—"The study of the changes produced in bodies by heat is based upon certain *fundamental laws* as the laws of Mariotte (or Boyle) and of Gay-Lussac (or Charles)." He defines absolute temperature as what is shown by an air thermometer, the zero of which is 273° C. below the ordinary zero. If adequate explanation were given, there might be no objection to these and other statements; but I am inclined to think that the ordinary reader will find such an introduction misleading. I think that some difficulty would be cleared up if the author proved the truth of the fundamental equations for perfect gases, instead of merely assuming their truth; it would lead to a much simpler treatment of the next two chapters. Parenthetically, I would observe that he is quite mistaken in thinking that a *small* error in measuring clearance in a gas engine cylinder will lead to very wrong values of k in the expansion curve, pv^k constant.

It would be interesting to know what the author means when, after speaking of Regnault's value 0·48 for the specific heat of steam, he says, "and this is about the same value as it would have if treated as a permanent gas, and its density calculated from its molecular weight." I think that there is almost no point of view from which this statement must not be regarded as absurd.

On the whole, the author may be said to have given an account of the subject which it is worth while for a beginner to study, should he not be able to lay his hands on the several better accounts which have already been published in England. It is a pity that the translator did not think it worth while to alter Prof. Boulvin's illustrations, for these have compelled him to use letters which will give trouble to the English student. Rankine's letter ϕ is universally used in England and America for entropy; here we have S used instead. I am wrong in assuming that the use of the foreign illustrations compelled the translator to employ these letters; for I see that he follows Prof. Boulvin in using r for latent heat, λ for Regnault's total heat; and, of course, he uses A for Joule's equivalent. In a book intended for English engineers, I think that either C.G.S. units or English engineers' units ought to be used. In this translation we find the hybrid units of French engineers.

Many of the names mentioned in connection with the history of thermodynamics are quite unknown to me; I nowhere find any mention of the names of Lord Kelvin or of his brother the late Prof. James Thomson, who first demonstrated the connection between pressure, temperature and change of specific volume on change of state. Rankine's name is not mentioned either, although to the English engineer this seems like leaving out the name of Columbus in a history of the discovery of America.

In the section referring to "diagrams of CO_2 marking the critical point," of course the name of Dr. Andrews is not mentioned, but those of Regnault and Zeuner, Cailletet and Mathias are. Of course, A is used instead of J for Joule's equivalent throughout this book.

The translator says that Prof. Unwin has read over the proofs. I wonder whether he looked over the translator's preface, in which he states, among other curious things, that "entropy in its strict sense has no meaning if employed to represent the changes of state of a fluid flowing through a vessel, and more or less throttled in its passage." If he means that a foolish man may make mistakes in using a $t\phi$ diagram, he is right enough. But if he means that a certain quantity of stuff in a certain state has not just as definite a quantity of entropy as it has of pressure or temperature, he makes a mistake which is by no means an unusual one.

Perhaps, on the whole, it is well not to extend to the translator much of the credit which one may give to the author of the book. The author may never have heard of Rankine or the Thomsons or Andrews or Maxwell, but it is really unpardonable that in the translator's list of the works dealing with "the subject of entropy" there should be no reference to anything written by Rankine.

JOHN PERRY.

UNSCIENTIFIC NOTES.

Haunts and Hobbies of an Indian Official. By Mark Thornhill, author of "Adventures of a Magistrate in the Indian Mutiny." Pp. xii + 346. (London: John Murray, 1899.)

THIS is a collection of notes on various subjects jotted down by an Indian civilian, who, during part of his Indian career, kept a diary which was, he says,

> "chiefly devoted to observations on the birds, insects and animals whose acquaintance I made in my garden, or which I beheld on the bed of the river beyond."

Like many writers in the earlier half of the passing century, Mr. Thornhill uses the word animals in the restricted meaning of mammals. Occasional notes on the weather, on some of the natives of India, and on their habits, institutions and superstitions, and an account of a tour in the Deyra Dun at the base of the Himalaya, are added, and make a thoroughly readable and even an interesting book, though not one to which those desirous of information as to the "birds, insects and animals" of Northern India can be recommended to turn. The best portions of the work are those descriptive of the people of India and of the scenery; the changes of the seasons, and their effects, especially on insect-life, are also well described, but similar accounts have been given by other writers. The observations recorded were evidently made in parts of the North-western Provinces of India.

It is chiefly as a contribution to the zoology of Northern India that Mr. Thornhill's book demands notice here; and in this respect it would be difficult to find a more unscientific work. For science is essentially the accumulated experience of many men, and they who trust entirely to their own observations and neglect to make themselves acquainted with facts recorded by others, must not be surprised if the majority of their accounts are superfluous, and some of them erroneous. In the present work we have description after description of certain habits of the animal world well known to every Anglo-Indian, and useless to those unacquainted with India, because the author is unable to identify the animals observed. For instance, on p. 192 he describes in considerable detail a remarkable bird's nest. But although he must have devoted time and labour to obtaining and describing the nest, it does not appear to have occurred to him to inquire what bird built it, or whether any other observer had investigated this interesting form of bird-architecture. Yet from the description of the nest, and from the manner in which the structure was suspended from high grass, it is easy to recognise the nest of a weaver bird, and even to identify the species as probably the striated weaver bird *Ploceus manyar*. Any one who compares Mr. Thornhill's notes with those in Jerdon's "Birds of India," or better still with the elaborate account given in Hume's "Nests and Eggs of Indian Birds," must appreciate how useless the first-named are.

In the case just quoted, Mr. Thornhill, though his observations add nothing to what was well known before, does not mislead; so another instance may be taken, when his information is not only imperfect but incorrect. The following are extracts from his account (p. 118) of the animal well known in India under the name of the "musk-rat."

> "This rat, fortunately, does not make its residence in the houses, and indeed it only occasionally enters them, and then as a rule by night. I do not know whether after all it is a true rat. In appearance it more resembles a very small, nearly hairless, ferret. It is of a drab colour, and has that half-transparent look noticeable in young mice and unfledged chickens. Its presence is manifested by a squeaking cry, accompanied by an intolerably sickly odour, something resembling musk. The odour is so penetrating that, according to the European popular belief, it will pass through the glass of a bottle and flavour the liquor within. The fact is correct, but not the explanation. Beer and wine are certainly occasionally flavoured by these rats running among the bottles that contain them, but the odour penetrates not through the bottle, but through the cork."

The so-called musk-rat of India is, of course, a large shrew, and resembles a ferret about as much or as little as the common English shrew does. It varies in colour, but is generally slatey-grey to bluish-grey. If it does not spend the day actually in houses, it haunts their immediate neighbourhood, merely hiding in holes. Its presence is not necessarily manifested by any odour, as Sterndale has shown. Lastly, the absurd old story that liquors in bottles become impregnated with the peculiar odour of the secretion from the lateral glands of the musk shrew, whether the scent was supposed to pass